# Universal thermodynamic bound on quantum engine efficiency

Gershon Kurizki, Wolfgang Niedenzu, Abraham Kofman, and Victor Mukherjee

*Weizmann Institute of Science, Rehovot 76100, Israel*

The efficiency of heat engines is limited by the Carnot bound, attained when the engine cycle is reversible. Quantum engines fuelled by non-thermal (e.g., squeezed-thermal) baths have been shown to surpass this bound. Yet, their maximum efficiency cannot be determined by the reversibility condition, which may yield an unachievable efficiency bound above 1. This prompts the question: What does really limit the efficiency? We identify the fraction of the exchanged energy between a quantum system and a bath that necessarily causes an entropy change and derive a new inequality for the latter. This formulation reveals a universal efficiency bound for quantum engines which is invariably attained for the least dissipation over the engine cycle but does not imply reversibility, unless the baths are thermal. This bound thus cannot be solely deduced from the laws of thermodynamics. We illustrate these results for the practically-relevant Carnot- and Otto cycles energised by non-thermal baths, which are both shown to be restricted by our new efficiency bound.

[1] https://arxiv.org/abs/1703.02911